A Hedonic Pricing Analysis for Australian Thoroughbred Yearling Market

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A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Philosophy
in
Economics

August 2007


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Acknowledgement

I would like to express my sincere gratitude to my supervisor, Prof. Chong Tai Leung. Without his guidance and valuable suggestions, I would not be able to complete my thesis. Moreover, I am grateful to Prof. Kwong Kai Sun and Prof. Kwan Cheuk Chiu for their valuable comments and precious time in assessing my thesis. In addition, I would like to thank my classmates and friends for their encouragement and support. Lastly, I would like to express my thanks to my family for their wholehearted support and care.

Abstract

This study examines factors affecting the thoroughbred yearling price in the Australian racehorse auction market. The existing literature suggests that the yearling price mainly depends on the yearling's quality and its bloodline effect. The main contribution of this paper is to confirm the bloodline effect and to determine whether buyers exhibit any form of special preferences. The performance of the sire is usually considered the main factor in determining the auction price of a given yearling. However, using data from the two largest Australian auction companies, we confirm that the performance of the dam's progeny is an equally important factor. The performance of a dam's progeny is a good proxy of a yearling's ability as it shows the level of inheritance and thus, becomes one of the main factors influencing the auction price. Furthermore, other factors such as the physical features of the yearling and the supply-side information are also considered.

摘要

本文主要研究有關澳洲純種一歲馬匹的定價及其影響拍賣價之因素。 根據現有研究得知，一歲馬的拍賣價主要是由馬匹本身的體格素質和其血統有關。 本文目的除了確定體格素質及血統的影響外，還加入買家特殊喜好及不同拍賣會對馬匹售價的影響。 傳統賽馬大部份買家都把注意力放在父系身上，而本文發現母系賽道表現也是其中重要因素。 除此之外，從澳洲兩大拍賣馬匹公司資料中，本文發現母系子女的賽跑表現對其一歲馬的價格影響力與父系馬匹賽跑表現的影響力相約，這顯示母系兄弟姊妹的賽道表現能夠作爲週歲馬能力的一種重要參考，反映出父母的競賽能力遺傳到子女的水平。 另外，有關週歲馬的體格，身體特徵及同系馬匹供應等也是本文其中主要的考慮因素。

Content:

Chapter 1. Introduction and Motivation

1.1 Horse racing history

The thoroughbred is a horse breed specifically developed for racing. Most of the modern thoroughbred was found during the 17th century in England. The English mares were bred from imported Arabian stallions. Therefore, it has become the dominant breed in modern horse racing. Arabian horses are one of the oldest breeds in the world and the breed was found 4500 years ago. They were used in war and for hunting in the Middle East.

Breeds of horses can be divided into "cold blood", "hot blood" and "warm blood"[1]. "Cold blood" refers to horses which are heavier and calmer. Most of them are draft horses mainly used for carriage. "Hot blood" refers to Arabian horses, which are strong and energetic, and thus are more suitable for racing. "Warm blood" refers to any heavy horses crossed with Arabian horses; some of them are used for dressage. Arabian horses have developed in a desert climate and have good relation with nomads. This breed of horses has a high level of obedience and stamina. Furthermore,

[1] In biology, horses are mammals and thus are all warm-blooded creatures. The meaning of "hot blood", "cold blood" and "warm blood" is distinguished by context of equine description.

Arabian horses also have high spirit and sensitivity, which make them perfect for battle. They have outstanding stamina and good bones. Because of these physical features, they were imported into England for horse racing. Though there are other breeds which also have similar physical features, Arabian horses were chosen because they are gentle and easy to train. Their natural tendency to cooperate with man, their high spirit and their alertness make them different from other breeds.

1.2 The horse racing industry

Horse racing is one of the oldest sports in human history and has flourished as a sport of kings for thousands of years. It was started around 4500BC in central Asia by prehistoric nomadic tribesmen. In the time of the Roman Empire, there were chariot races which can be seen as early examples of horse racing. It was also a major event in the Greek Olympics starting in 638BC. Currently, chariot races still remain but with a different name. They are now called "harness racing" and are quite famous in North America. Unlike chariot races, horse racing has developed into different forms, such as harness racing, point-to-point racing, steeplechase racing, etc.. However, the most popular equestrian sport nowadays is thoroughbred racing.

The horse-racing industry is a huge agribusiness. In the US, there are around 35,000 thoroughbred registered each year. Most of the foals are born in Kentucky, Florida and California. This industry supports tens of thousands of jobs in each of those states. Horse racing generates a wide variety of job positions such as jockey, trainers, grooms, starters, farm workers who breed the horses, employees of gamble stations, employees of companies who transport horses, employees of auction houses, etc.. Besides, gambling, if legal, can generate a huge amount of tax revenues to governments. Hong Kong is one of the cities which allows horse-racing gambling. Although there is no horse breeding in Hong Kong, the horse-racing industry brings huge economic benefits to this city. The Hong Kong Jockey Club (HKJC), which is the only authorized organization for horse racing, employs 4,400 full-time and 20,000 part-time workers. Besides, HKJC is also the largest single tax payer in Hong Kong. During 2005-2006, it contributed around 8.6% of all taxes collected by the Inland Revenue Department. The betting duty and profit tax were HK$12.405 billion. In Australia, the economic value of the Victorian thoroughbred racing industry is about AUS$2.2 billion per annum and over 66,000 people are employed in the industry, which is equivalent to 22,000 full-time positions, according to the Racing Victoria Limited. In 1997-1998, the total taxes related to thoroughbred racing levied

by the Australian government were AU$553.8 million[2] and the net takings were around AU$1430 million.

In the production of racehorses, breeders play an important role. In order to produce a high quality racehorse they have to choose the appropriate broodmare and stallion. Selecting a mare and a stallion is crucial in determining the quality of foals. After buying the mare, breeders will send it to the stallion for mating. However, this process is time consuming and involves high traveling cost. Besides, there are potential risks such as the kicking of the stallion by the mare and the spreading of sexual diseases between mare and stallion. The advances in biotechnology have enhanced artificial insemination and embryo transfer, but those techniques are not allowed in the thoroughbred industry. All yearlings are required to register and each of them has its identification card providing breeding, marking, gender, brand and microchips details. All registered foals must be bred through live cover. Artificial insemination and fertility are not permitted. According to the International Federation of Horseracing Authority, "A natural gestation must take place in, and delivery must be from, the body of the same mare in which the foal was conceived. Any foal resulting from or produced by the processes of Artificial Insemination, Embryo

[2] Figures are collected from the Australian Bureau of Statistics, survey of gambling industries, Australia, 2000-01. Website: http://www.abs.gov.au

Transfer or Transplant, Cloning or any other forms of genetic manipulation not herein specified, shall not be eligible for recording in a Thoroughbred Stud Book approved by the International Stud Book Committee." [3] The reason for implementing this policy is that the thoroughbred industry does not aim at producing standard racehorses but at introducing some genius or outliers by live cover. This makes the thoroughbred industry a unique market when compared to other livestock markets. The only way to increase the quality of foals is to choose good quality sires and dams. Therefore, live-cover breeding is risky for breeders because of the potential risks of genetic diseases.

1.3 Yearling Sale in Australia

The sales of thoroughbred horses in Australia are mainly conducted by auctions, which are dominated by two major auction houses–the William Inglis and Son Ltd and the Magic Millions Sales Pty Ltd. The main functions of these two auction houses are auctioning thoroughbreds, promoting the auction events and facilitating transactions between buyers and horse breeders. The William Inglis, established in Sydney in 1867, is one of the oldest and largest thoroughbred auction companies in

[3] By International Agreement of Breeding and Racing, Article 12- Definition of a Thoroughbred

Australia. It has its "Yearling Sale Series" which comprises five specific yearling sales every year. The Newmarket Complex in Sydney is host to the Classic Yearling Sale and the Australian Easter Yearling Sale while the Premier and Autumn Sales are held at the Oakland Complex in Melbourne. The Scone Sale is held in Scone but has a relatively smaller scale. Similar to the William Inglis, the Magic Million also has five main yearling auctions–the Conrad Jupiters Yearling Sale, the Perth Yearling Sale, the Adelaide Yearling Sale, the Gold Coast Premier Yearling Sale and the National Yearling Sale. Table 1 shows all of the auctions held regularly between January and June. The flagship events of these two auction companies are the Australian Easter Yearling Sale and the Conrad Jupiters Yearling Sale.

Table 1: Basic information for yearling auctions in Australia

Name of Auction	Date	Total yearling
WI Classic Yearling Sale	16th-17th January, 2005	569
WI Premier Yearling Sale	13th-16th February, 2005	597
WI Australian Easter Yearling Sale	29th-31st March, 2005	598
WI Autumn Yearling Sale	17th-18th April, 2005	374
WI Scone Yearling Sale	22nd May, 2005	200
MM Conrad Jupiters Yearling Sale	6th-12th January, 2005	1151

MM Adelaide Yearling Sale	22nd-27th February, 2005	684
MM Perth Yearling Sale	8th-11th March, 2005	505
MM Gold Coast Premier Yearling Sale	20th-22nd March, 2005	649
MM National Yearling Sale	9th-10th June, 2005	382
Total		5709

1.4 Motivation

The main purpose of this study is to test the bloodline effect and the other factors affecting the yearling price. Yearlings are horses aged between one and two years old and which do not have any track records. Understanding the pricing model of yearlings is especially important for breeders and horse buyers. Breeding is a risky business. Breeders pay the stud fee now in the hope of selling the yearling at a higher price in the future. They will suffer from losses if there is dystocia or if the yearling has other genetic diseases such as Severe Combined Immunodeficiency (SCID), Occipital Atlanto-Axial Malformation (OAAM), etc.. Buyers, on the other hand, pay a high price for a yearling with the expectation that the horse will perform well and win prizes. Owning a racehorse is costly. A horse needs around 2.5% of its weight in food everyday. The horse owner also has to rent a stable, hire grooms, trainers,

veterinarians, etc.. To achieve extreme speed, modern thoroughbreds are trained to increase their muscle mass and reduce their bone mass. Because of their light skeleton and of the abnormal weight load they carry, racehorses easily suffering from injury. Leg injuries may be life threatening because the weight of a horse is evenly distributed on its four legs to prevent circulatory problems. Therefore, owning a racehorse is costly and risky. However, many people still buy racehorses. Apart from the investment purposes, horse owners also get utility when their horses win a famous race. Some genius racehorses like Danehill, Silent Witness and Redoute's Choice are very famous and their owners can share the glory of winning well-known races. However, it is difficult to identify which horse has the potential and ability to win in track. The potential of a yearling can be told by its pedigree and appearance. Horse judging is an art. It is sometimes very subjective. The bone structure, mouth, eyes, pace, etc. are difficult to quantify and there is no standard rule to measure these characteristics. Figure 1a and Figure 1b show two yearlings which were sold in the Australian Easter Yearling Sale in 2005. By looking at the picture, it is rather difficult to distinguish which of them is more valuable. Besides, it is difficult for potential buyers to visit all the stables before the auction. Since pedigree tables are included in the catalogues and are publicly accessible before the auction is held, most buyers choose to rely on these pedigree tables.

For years, it has been said that a good lineage will determine the performance or ability of the next generation of racehorses. This kind of view is not only applied to racing horses but also to most animals and to human. There is an idiom: "like father, like son". It is believed that there is a causal relationship between the performance of a sire or a dam and the ability of its foals. Thus, if there is perfect information about the lineage of a horse, quality horses should be sold at a high price. In reality, it is difficult to measure the quality of the horses, especially since all yearlings have no track records. Buyers do not have accurate information about the quality of yearlings while the breeders or sellers may know more about their yearling's potentials. Some criteria like shape, weight and appearance are too subjective for buyers to measure the quality of yearlings. If a horse does inherit good quality from its sire, we can easily measure the quality of the horse and explain why some horses are more expensive than others.

Existing literature mainly focuses on the effects of the sire in heredity. The influence of the dam is surprisingly understudied. For thousands of years, there has been a bias towards the importance of the male over the female in terms of ability inheritance. However, each parent should provide, on average, 50% of the genetic makeup of

their offspring. The effect of the performance of the dam should be of the same importance as that of the sire. This study examines the impact of the dam's performance on the yearling price.

Besides the bloodline effect, some other factors are also useful in explaining the prices of yearlings. The number of horses sold in the same auction, which represents the supply-side effect, is one such factor. The popularity of the auction is another possible factor influencing horse prices. Although there are horses for sales throughout the year, some of the auctions are more popular than the others. Different from other countries, there is keen competition between two auction companies in Australia. This study is the first to investigate the effect of the difference in auction popularity on yearling prices.

Chapter 2. Literature review

The hedonic pricing model has been examined by Lancaster (1966) and Rosen (1974). It has been used to study the housing price (Witte et al., 1979) and the auction prices of vehicle registration marks (Du, 2004). Recently, there are studies on the hedonic pricing of horses. Buzby and Jessup (1994), Robbins and Kennedy (2001) have suggested factors that are important in pricing a yearling in the Kentucky auction. Using the data of Kenneland between 1980 and 1990, Buzby and Jessup (1994) examine the impact of macroeconomic variables, such as, interest rates, tax changes and gross foreign purchase on the yearling price. These macro variables are found to be significant and the passage of the 1986 Tax Reform Act is found to have an adverse impact on yearling prices. The result for Buzby and Jessup is a little bit different from other studies. They find that the difference in gender is not statistically significant to explain horse prices. Besides, they also find that time is positively related to prices. It is not surprising since there was inflation over the sample period.

Chezum and Wimmer (2001) study the adverse selection in auction for yearlings. They argue that sellers have more information about the true quality of yearling than the buyers. However, buyers know that sellers can be divided into two types. Some

sellers will sell part of their horses and reserve the high quality horses for racing. The other type of sellers will sell all the horses they breed. Thus, buyers may offer a lower price for the first type seller since the horses sold are of lower quality. They find that the price of the thoroughbred yearlings is affected by adverse selection.

Robbins and Kennedy (2001) show the important role of the dam on yearling pricing. They find that macroeconomic variables play a small role in pricing. Besides, the effect of the dam on yearling pricing mainly depends on the performance of the dam's progeny. They find that buyers will not pay more for a dam without progeny than for a dam with a progeny that has raced but never won. However, the authors do not explain the result. Nearly all of the models for pricing the yearlings are log-linear. Commer (1990) has used the linear functional form. Buzby and Jessup (1994) rerun the regression by using a linear functional form for yearling specific variables but the explanatory power has dropped. There is no significant difference between using a linear form and a log-linear form. Besides, Robbins and Kennedy (2001) conduct a simple performance analysis. They estimate a Tobit model for the relationship between the earning of 3-year performance and the yearling price. Their result shows that when the yearling price exceeds US$75,000, the probability of winning a stakes race will exceed 50%. However, 403 out of 1316 observations have zero earnings

and some of the horses do not have 3-year performance record. The fact that some horses have never raced after being purchased may result in overestimation.

Neibergs (2001) studies the factors affecting the price of broodmare and confirms the importance of a good lineage. Besides, he finds that a barren mare is less valuable and that the reproduction efficiency measure is not significantly different from zero. He claims that the study has higher explanatory power when compared to the results of Lansford (1998) and Buzby and Jessup (1994). However, the target products are not totally equivalent. Broodmares and yearlings are actually different products and the potential buyers are different. It may therefore not be appropriate to compare those two different products. Yet, we can understand how physical factors affecting the price of broodmares may also affect the price of yearlings.

Chapter 3. Data

3.1 Categories of variables

In this study, we examine the impacts of 20 variables on the yearling pricing. The variables are divided into four main categories. Each category represents a specific characteristic of a yearling's profile and bloodline information. The yearling specific variables are used to describe the physical characteristics of the yearling. The sire and dam factors consist of variables related to information on the yearling's parents and its siblings. The market variables include the supply information and the auction dummy. The definitions of the variables are shown in Table 2.

Table 2: Description of dependent variables and regressors

Variables	Description	Unit of measure	Expected sign
Dependent Variables			
LNPRICE	Natural logarithm of the yearling price	$	N/A
Yearling specific characteristics			
BMONTH	the month that the yearling was born	Month	-
COLT	the sex of yearling; colt =1, filly=0	Binary	+
Color	The color includes bay, brown, chestnut, grey black and mixed color.	Binary	/

Sire characteristics

SAGE	Age of the father of the horse	Years	-
SWIN	Number of races the sire has won	No. of race	+
DI	Dosage Index for the sire	Number	-
SCHAMP	= 1 if sire awarded either Australian Champion Horse of 2/3YO, Horse of the Year or first three in Leading Sire; otherwise, =0	Binary	+

Dam characteristics

DAGE	Age of mother of the horse	Years	-
DWIN	Number of races won by mare	No. of race	+
RACEWIN	=1 if dam has raced and won the first place; otherwise, =0	Binary	+
RACEWIN0	= 1 if dam has raced but did not win; otherwise, =0	Binary	-
DCHAMP	= 1 if dam awarded Australian Champion Horse of 2/3YO, Horse of the Year; otherwise, =0	Binary	+
FOAL1	= 1 if yearling is the first foal of its dam	Binary	-
WINSIB	Number of winning siblings by same dam	Number	+
WINSIBD	=1 if any sibling is winner; otherwise, =0	Binary	+

Market characteristics

SAMESIRE	Numbers of yearling with same sire supplied within the same auction sale	Number	-
Auctions	Auctions include 10 auctions held by William Inglis and Magic Million.	Binary	/

3.2 Data Description

The data are mainly collected from the websites[4] of the two biggest Australian thoroughbred auctioneers, namely the William Inglis & Son Ltd (WI) and the Magic Millions Sales Pty Ltd (MM). Sire and dam specific variables are collected directly from the catalogues. A sample of the catalogue is shown in Appendix 1. Each catalogue includes the basic information on the yearling such as pedigree, color, sex, birthday, lot number, pedigree table and information on the performance of sire and dam. Sibling's performance is also included. Note that all of the siblings are the progeny of the dam. We collect the sales results of the 10 largest auctions in Australia in 2005 and a total of 4,149 observations are obtained. These 10 auctions are chosen because they are the largest regular auctions in Australia. Table 3 shows the distribution of yearlings sold in different auctions. The MM Conrad Jupiters Yearling Sale is the largest yearling sale in Australia. There were 876 yearlings sold in this auction. The WI Australian Easter Yearling Sale has the highest average price among all the auctions in Australia. These two auctions are the most important events for WI and MM.

[4] The catalogues are collected from the websites of these two auction companies and the data are compiled by obtaining the information in the catalogues.

Table 3: Distribution of Yearlings sold in Australia

Name of Auction	Number of yearling sold	Average price(AU$)
WI Classic Yearling Sale	415	34,792.7
WI Premier Yearling Sale	451	52,130.8
WI Australian Easter Yearling Sale	436	207,633
WI Autumn Yearling Sale	272	10,495.0
WI Scone Yearling Sale	159	12,926.9
MM Conrad Jupiters Yearling Sale	876	83,717.5
MM Adelaide Yearling Sale	493	33,856
MM Perth Yearling Sale	371	24,447.9
MM Gold Coast Premier Yearling Sale	413	15,169.5
MM National Yearling Sale	263	27,550.4
Total	4,149	59,305.6

Table 4 shows the summary statistics of the yearling price and the independent variables. Most of the data are collected from the auction catalogues[5] of each auction. The variables in this paper can be divided into four main categories, namely the

[5] Sample of catalogue can be found in Appendix 1

yearling specific factors, the sire factors, the dam factors and the market factors. The most expensive yearling in Australia in 2005 was sold at the WI Australian Easter Yearling Sale for AU$2.5 million. The average price of yearling sold in WI and MM was AU$59,305.6 in 2005. However, the average price for WI was higher than that of MM. The average birth month is 9.46. Due to the seasonal breeding behavior, most horses are born in spring, which corresponds to the period between August and October in the Southern Hemisphere. Besides, there are totally 2,461 colts in our sample, which implies that around 60% of the yearlings sold are colts. Most of the yearlings are bay while only 18 yearlings are black. The average age of sire is 12 and the average number of race won by sire is 5.53. Around 29% of the sires have won special prizes such as Champion 3-Year Old horse, Horse of the Year, Leading Sire, etc.. For the dam's factors, the average age of the dam is similar to that of the sire. For dams aged less than 12, the average number of winning race is 1.29 while for those older than 12, the average is 2.24. The reason for the difference is that most well-performed dams tend to continue being trained and prepared for races, rather than being used for mating and breeding. During gestation, the mares cannot race or be trained. Therefore, the mares that have a good track record will only be retired and used for breeding once they are unable to race. We can therefore expect that mares with good track records will start breeding at a later age, and vice versa. The average

number of race won by a dam is 1.75 but the standard deviation is high since some mares may not ever race, while some outliers perform very well on track. Moreover, 23% of the dams have raced but never won. Only 18 dams have been awarded special championship titles, which is much less in proportion as compared to the sire. One explanation is that sires are physically stronger than dams. The other reason is that a sire can mate for breeding several times while a dam can mate only once a year. Sire can race after mating while the mare cannot if it is pregnant. 18% of the yearlings sold are the first foal and on average, there are 1.33 winning sibling for each yearling. The siblings here only represent the siblings from the same dam. On average, there are around 9 yearlings with the same sire sold in the same auction.

Table 4: Summary of statistic for dependent and independent variables

Variables	Mean	Std. deviation	Minimum	Maximum
Dependent Variables				
PRICE	59,306	107,267	500	2,500,000
Yearling specific characteristics				
BMONTH	9.46	1.02	1	12
COLT	0.58	0.49	0	1
COLOR	/	/	/	/
Sire characteristics				
SAGE	12.02	3.90	7	27
SWIN	5.53	2.98	0	21
SCHAMP	0.29	0.45	0	1
DI	2.46	1.60	0.38	15

Dam characteristics				
DAGE	12.03	4.00	5	27
DWIN	1.75	2.36	0	16
RACEWIN0	0.23	0.42	0	1
DCHAMP	0.004	0.066	0	1
FOAL1	0.18	0.38	0	1
WINSIB	1.33	1.81	0	13
Market characteristics				
SAMESIRE	9.50	8.53	1	38

Chapter 4. Thoroughbred Yearling Hedonic Pricing Model

As mentioned before, the independent variables can be classified into 4 main groups. Therefore, the yearling price can be generally specified as:

$$P_i = f(x_{i,y}, x_{i,s}, x_{i,d}, x_{i,m})$$

P_i is the yearling price, $x_{i,y}$ is a vector of the yearling specific variables, $x_{i,s}$ is a vector of the sire characteristic variables, $x_{i,d}$ is a vector of the dam characteristic variables and $x_{i,m}$ is a vector of the market characteristic variables.

The summary statistics of our dependent variable, the yearling price, are shown in Table 5.

Table 5: The summary statistics of the yearling price with entire sample (in Australian dollars)

	Mean	S. D.	Median	Max	Obs
Price	59,306	107,267	27,000	2,500,000	4,149

We can see that the standard deviation of the yearling price is quite high relative to its mean. As shown in the table, the mean is much higher than the median. Figure 2a shows that the distribution of the yearling price is positively skewed. Table 6 shows

the percentile information of the yearling price for the entire sample. Note that in the lower percentile, the variation in prices is relatively small compared to the variation of prices in the high percentile. The yearling price increases sharply between the 80th percentile and the 99th percentile. The increase is even more than double from the 95th percentile to the 99th percentile. There may be some outliers in our sample which will increase the variation and thus, reduce the significant level of independent variables.

Table 6: The percentile information of the yearling price

Variable	Percentile	Centile (in AU$)
Price	30	14,000
	35	17,000
	40	20,000
	45	22,000
	50	26,000
	55	30,000
	60	36,000
	65	42,000
	70	50,000
	75	60,000
	80	75,000
	85	100,000

	90	140,000
	95	210,000
	99	480,000

4.1 The log-linear model

To reduce the high deviation of prices, one method is to transform the yearling price into natural logarithm. Following the previous literature, a log-linear regression model is employed to identify the explanatory power of yearling specific factors, sire & dam factors and buyer & auction specific factors on the yearling price. The advantage of using a log-linear function is that the relationship between the dependent variable and the explanatory variables can be interpreted in terms of percentage. The summary statistics of the log yearling prices, LNP, are shown in Table 7. The standard deviation of LNP is relatively smaller when compared to its mean. Note also that the median is close to the mean now.

Table 7: The summary statistics of the log yearling price (in Australian dollars)

	Mean	S. D.	Median	Max	Obs.
LNP	10.2144	1.2491	10.2036	14.7318	4149

4.2 Sub- sample estimation

Another method to smooth the high variation is to remove the top 1% observations and only focus on the 99% sample. The reason for this is to downplay the effect of outliers. Table 8 shows the summary statistics of the yearling price with the 99% sub-sample. The standard deviation is largely reduced. The coefficient of variation is much smaller than the one for the entire sample.

Table 8: The summary statistics of the yearling price with 99% sub-sample (in Australian dollars)

	Mean	S.D.	Median	Max.	Obs.
Price	51916	68,569	26000	480,000	4107

The hedonic pricing regression model can be specified as follows:

$$P = \beta_1 + \beta_2 BMONTH + \beta_3 COLT + \beta_4 BAY + \beta_5 BROWN + \beta_6 GREY + \beta_7 BLACK + \beta_8 MIXED + \beta_9 SAGE + \beta_{10} SAGE2 + \beta_{11} SAGE3 + \beta_{12} SWIN + \beta_{13} DI + \beta_{14} SCHAMP + \beta_{15} DAGE + \beta_{16} DWIN + \beta_{17} RACEWIN0 + \beta_{18} DCHAMP + \beta_{19} FOAL1 + \beta_{20} WINSIB + \beta_{21} WIautumn + \beta_{22} WIclassic + \beta_{23} WIpremier + \beta_{24} WIscone + \beta_{25} MMadelaide + \beta_{26} MMconrad + \beta_{27} MMpremier + \beta_{28} MMperth + \beta_{29} MMnational + \beta_{30} SAMESIRE + \varepsilon$$

The log-linear model is somewhat similar to the linear price model. The only difference is that the dependent variable is transformed.

$$LNP = \beta_1 + \beta_2 BMONTH + \beta_3 COLT + \beta_4 BAY + \beta_5 BROWN + \beta_6 GREY + \beta_7 BLACK + \beta_8 MIXED + \beta_9 SAGE$$
$$+\beta_{10} SAGE2 + \beta_{11} SAGE3 + \beta_{12} SWIN + \beta_{13} DI + \beta_{14} SCHAMP + \beta_{15} DAGE + \beta_{16} DWIN + \beta_{17} RACEWIN0$$
$$+\beta_{18} DCHAMP + \beta_{19} FOAL1 + \beta_{20} WINSIB + \beta_{21} WIautumn + \beta_{22} WIclassic + \beta_{23} WIpremier + \beta_{24} WIscone$$
$$+\beta_{25} MMadelaide + \beta_{26} MMconrad + \beta_{27} MMpremier + \beta_{28} MMperth + \beta_{29} MMnational + \beta_{30} SAMESIRE + \varepsilon$$

In these two models, CHESTNUT and WIeaster are the controlled variables.

4.3 Expected result

Yearling specific factors are used to describe the physical characteristics of the yearlings. The color and the gender of the yearling are included and they are binary variables. Yearlings are classified into six colors which are bay, brown, chestnut, black, grey and mixed color. Yearling with mixed color are horses with color like brown or bay, bay or black, etc.. The skin color is classified when the foal is born and is registered in its identification card. The estimation results of the color dummies reflect the preference of the buyers for skin color.

It is expected that a colt (young male horse) should be more valuable than a filly (young female horse). Since the gestation period of a horse is approximately 340 days, mares can normally have only one foal each year. Most mares can only have up to twelve progeny during their lifetime. Furthermore, if a female horse is pregnant, it

cannot race during the gestation period. Therefore, colts are expected to be more expensive as they can mate with several mares over a year. Moreover, biologically, male horses are physically stronger than female horses. Although a female horse only weights 4 pounds less than a male horse on average, the male still has a significant physical advantage. Therefore, buyers are willing to pay a premium for a colt.

The age of a yearling is another factor influencing its price. As Hastings (1987) mentions, yearlings which are born earlier should be more developed and thus, more expensive. It is because buyers do not need to wait until the horse become mature enough for training and racing. In our model, the variable BMONTH is the month that the yearling was actually born. In Australia, there is an official covering period which is used to standardize the age of racehorses. The August 1st is the official birthday for all horses in Australia. The covering season is between September 1st and May 31st . An older yearling will save the cost of breeding. Therefore, we expect the coefficient of BMONTH to be negative.

Sires also play an important role in determining the price of the yearlings. If our assumption of "like father, like son" is correct, the performance of a sire should positively affect the ability of his foals and thus will yield a higher yearling price. We

use the number of races won by a sire as a proxy of the sire's ability. If its sire has excellent performance, a yearling will have a higher chance to be successful as well. Consequently, yearlings whose sire won a special championship title are expected to be sold for a higher price. Special championships include the Australian Champion Horse in 2/3 Years Old, Horse of the Year or First Three in Leading Broodmare or Sires. On the other hand, the Dosage Index (DI)[6] which is popular and commonly used in the industry is also included in our investigation. DI is a quantitative measure of pedigree. This index is an estimate of speed and stamina according to the lineage performance. A racehorse with high DI is unlikely to have enough stamina to capture long distance races. A sire with low DI is expected to transmit its good stamina to its progeny. Since most Derby races are longer than one mile and one-quarter, e.g., Melbourne Cup covers 3,200 meters, horses with high DI are unlikely to win. DI is expected to be negatively related to the yearling price. Since Derby races are normally high stake races, horses which are eligible to participate in a Derby race will have a higher expected value. In addition, the age of the sire should be related to the yearling price. It is equal to the auction year minus the birth year of the sire. Therefore, the age of a sire is not constrained by its race life since the sire can still be used for mating after having retired. We expect the relationship between the yearling

[6] Dosage index is created by Steven A. Roman. For details of the calculation, please refer to website: http://www.chef-de-race.com/dosage/review.htm

price and the age of the sire to be nonlinear. This is because a young sire has better and stronger sperm. Healthy semen is very important since it affects the level of inheritance of the sire's ability to its progeny. Yearlings with old sires are also more expensive because of the scarcity of those sires' progeny. Some breeders would like to buy a stallion whose line is almost extinct.

The next category is the dam's characteristics. Similar to the sire characteristics, the performance of the dam is also important in yearling pricing. Conventional breeding theories focus on the impact of the sire line. The influence of the dam is rarely examined. Recent researches show that some physical characteristics of progeny, such as heart size and DNA in mitochondria are affected by the mother. The genetic makeup should be affected by both father and mother. Therefore, the performance of the dam should share equal importance in the determination of the yearling's potential. Consequently, the number of race that a dam won (DWIN) and whether or not the dam has won a major championship (DCHAMP) should also be positively related to the yearling's price. A dam that has raced but has never won (RACEWIN0) will be identified as having poor genes and thus, the variable is expected to have a negative effect on the yearling price. The age of dam (DAGE) is also important to the yearling price. The reason is that the risk of having an unhealthy or weak foal will be

higher if the mother horse is too old to have a baby. Besides the parent's influence, we would also like to examine the impact of the performance of siblings on the yearling price. Sharing genes from the same dam, the performance of its sibling should be a good proxy of the ability of a yearling. The variable WINSIB is the number of winning siblings that the yearling has. It is expected to have a positive effect on the yearling price. Besides, the price for the first foal of the dam should be lower since there is no reference for buyers to obtain information about the level of inheritance of their dam.

The last category of variables contains the supply and auction-specific information. There are two main factors affecting the relationship between the yearling price and horse supply. If the market has a high demand for the progeny of a particular stallion, such as Danehill and Redoute's Choice, breeders are inclined to breed more of such yearlings in order to sell them in auction at a higher price. However, increasing the number of the progeny of a particular sire may have a negative impact on price because of the increased availability.

Another objective of this paper is to examine whether the popularity of an auction has any influence on the price of yearlings. For the William Inglis, the Australian

Easter Yearling sale is the flagship event while the Conrad Jupiters Yearling Sale is the famous sale for Magic Million. Most breeders would like to sell their horses in these famous auctions for a higher profit. If the horses cannot be sold, the investment is considered as failed. Breeders will be inclined to participate in the famous auctions when they want to sell horses with a higher stud fee and famous sires. Therefore, we expect the yearlings sold in the WI Australian Easter Yearling Sale to have a premium since this sale is the most famous yearling sale in Australia.

Chapter 5. Estimation Results

In this chapter, the Ordinary Least Square (OLS) estimation results of our hedonic pricing models are reported.

5.1 Estimation result for LNP

In this section, the empirical results for different models will be shown. Table 9 shows the coefficients and t-values for the log-linear model. The R-square is 0.5298. Note that if the price variations increase with the yearling prices, the variance is not constant and heteroskedasticity exists. The assumption of constant variance would therefore be violated[7]. To check whether there is a problem of heteroskedasticity, we employ the Breusch-Pagan (1979) [8] test to see whether the variance of fitted value is constant. The result shows that there is heteroskedasticity. In order to obtain consistent estimates of the variance, we used the robust variance estimate proposed by White (1980). The White Hetroskedastic Consistent estimation results are reported below. Furthermore, the normality of residuals is tested by using the

[7] Although the least squares estimator is still a linear and unbiased estimator, it is no longer the best linear unbiased estimator. The standard errors computed for the least squares estimators are incorrect and the hypothesis tests become misleading.

[8] The regression diagnostics are shown in Appendix 2

Shapiro-Wilk test. The result shows that the null hypothesis is not rejected. It means that the residuals of the log-linear model follow a normal distribution which is consistent with our assumption. Appendix 2 presents the details of the tests.

Table 9: Coefficients and t-values of Model A for the independent variables

Variables	Coefficient	t-value
BMONTH	-0.090	-6.36***
COLT	0.218	7.99***
BAY	0.072	2.18**
BROWN	-0.0006	-0.02
GREY	0.121	1.72*
BLACK	0.156	0.76
MIXED	0.006	0.11
SAGE	-0.449	-5.16***
SAGE2	0.032	5.16***
SAGE3	-0.00066	4.89***
SWIN	0.024	4.99***
DI	-0.013	-1.56
SCHAMP	0.225	6.83***
DAGE	-0.049	-7.73***
DWIN	0.043	6.45***
RACEWIN0	-0.134	-3.74***
DCHAMP	0.560	2.47**
FOAL1	-0.120	-2.89***
WINSIB	0.104	8.34***
WIautumn	-2.385	-34.55***
WIclassic	-1.256	-22.04***
WIpremier	-1.012	-17.75***
WIscone	-2.179	-27.52***
MMadelaide	-1.329	-22.11***
MMconrad	-0.744	-15.01***
MMpremier	-2.119	-32.69***

MMperth	-1.653	-27.67***
MMnational	-1.780	-22.33***
SAMESIRE	0.022	11.66***
CONSTANT	14.096	34.11***
R^2	0.5298	

Notes: 1. Dependent variable= LNP, natural logarithm of the yearling price.

2. In Model A, CHESTNUT and WIeaster are the controlled variables.

3. *, **, *** represent the 10%, 5% and 1% significance level respectively.

Model A is our benchmark model. We estimate the effects of yearling specific factors, bloodline factors and other market factors on the yearling price in auction. For yearling specific factors, we find that BMONTH is statistically significant. As expected, it is negatively related to LNP. Recall that the variable BMONTH is assigned in terms of the birth month. The foals born one month earlier are priced 9% higher on average. All yearlings have a common birthday which is August 1st in Australia. Among these yearlings, some are more mature and ready to be trained while some are not. Therefore, buyers are willing to pay more for a more mature yearling since they will cost less to breed. This confirms the results of Buzby and Jessup (1994), Robbins and Kennedy (2001) and Vickner and Koch (2001).

Another yearling specific factor, COLT is also statistically significant and positively related to LNP. On average, a yearling can be sold at 21.8% more if it is a colt. The

result is somewhat different from Hastings (1987) and Buzby and Jessup (1994), who find no statistical difference in the yearling pricing between male and female horses. Vickner and Koch (2001) obtain a slightly negative coefficient. Our result supports the works of Commer (1991) and Robbins and Kennedy (2001), who find that buyers are willing to pay a premium for a colt. As we have mentioned, the physically stronger muscle and valuable semen may be the possible reasons for this higher price.

In this study, we also investigate the effect of skin color on the yearling price in order to determine whether there is any special preference for skin color. We treat CHESTNUT as the controlled variable. It is shown that yearlings with chestnut color have the lowest price among all colors on average. The BAY variable is statistically significant, which suggests that yearlings with bay skin color are more expensive.

We also find that sire performance is crucial in determining the inheritance of ability to its progeny. We obtain positive coefficients for SWIN and SCHAMP. An additional race won by a sire increases the yearling price by about 2.4%. Special Championship titles like "Horse of the Year" are very famous and only a small number of racehorses have been awarded this kind of honor. This is actually a proof

of the quality of the sire. According to our estimates, yearlings are priced 22.5% higher on average if their sires have been awarded a special championship title.

The result of SAGE is similar to what we expected. SAGE is not linearly related to the yearling price. We use SAGE2 and SAGE3 to show the relationship between SAGE and the yearling price. The variable DI is negatively related to LNP. DI is used for indicating the relationship between track performance of a yearling's parents and track distance. This index, which is popular within the breeding industry, is a proxy for stamina and the speed of sire and dam and. Recall that horses with high DI are less likely to win in long distance races. Since most long distance races have relatively higher prize money than sprints races, sires with lower DI are more valuable. We expect the yearling to have a higher chance to inherit better physical condition if its sire has a lower DI. Note that the coefficient of DI is negative but it is not statistically significant.

Considering the effect of the performance of the dam on the yearling price, DAGE is negatively related to the yearling price and the result is consistent with our prediction. Good physical condition in young age plays an important role in mating and gestation. On the other hand, the performance of the dam is crucial as well. DWIN is

statistically significant and positively related to LNP. An additional race won by dam increases the yearling price by almost 5%. However, yearlings with RACEWIN0 are sold 13.4% lower than other horses. It is obvious that a dam with a good track record is more valuable. DCHAMP also has a positive effect on the yearling price. Since very few dams have been awarded special championships, having a dam with such honor contributes to a 55% price increase. Dams that have raced but never won are definitely less valuable because of their lower demonstrated ability in races.

Next, we are going to investigate whether or not an unraced dam is more valuable than a raced dam that never won. Generally speaking, an unraced dam has no track record which can provide information about the dam's performance. However, a dam that has never raced should be more valuable than a dam that raced but never won. The reason is that unraced dam may be either a good or a bad performer, while RACEWIN0=1 is a clear signal of poor performance. Buyers will pay a premium for a dam with uncertain performance rather than a dam with proven poor performance. We construct a dummy variable, RACEWIN which indicates whether the dam has raced and won. The controlled variable in Model B is unraced dam. As shown in Table 10, we compare the price difference between yearlings with an unraced dam and yearlings with a dam that raced but never won. The result is consistent with our

expectation. A yearling with a poor performing dam will have a lower value than a yearling with an unraced dam.

The performance of siblings is a good proxy of the level of heredity. FOAL1 means the yearling is the first foal of the dam. Model A shows that the first foal yearling is priced 10% lower on average. This is because in that case there is no relevant information about the level of inheritance. Besides, a yearling with more siblings which are the winners can also be sold at a higher price. Having more winning siblings indicates that the yearling's dam tends to transmit good ability to its progeny. Thus, siblings' performance is a strong reference to the prospect of a yearling. Yearling price increases more than 10% when one more siblings is a winner. Model B is introduced to investigate the importance of sibling's information. Recall that FOAL1 indicates that the yearling does not have any siblings for references. We construct a similar dummy variable, WINSIBD, which indicates that the yearling has one or more winning siblings. A yearling with winning siblings is priced higher and there is no statistical significant price difference between the first foal and a yearling with siblings who has never won.

Next, we will discuss the impact of the popularity of specific auctions on the yearling

price. We use WIeaster as a control variable because the Australian Easter Yearling Sale is the most famous yearling auction in Australia. The result of Model A shows that all other auction dummy variables have negative coefficients and all of them are statistically significant. Breeders with high quality yearlings will choose to sell their horses in a reputable auction. Breeders may have inertia in selling their yearlings with the auction company. Outstanding breeders do not want to sell their horses in other new auction company since their yearlings may not be sold at a good price.

Moreover, the availability of yearlings with same sire (SAMESIRE) is also positively associated with the yearling price. As previously mentioned, if there are more yearlings from the same sire, buyers have more choices. However, our result shows that yearlings with more half brother/sister sold in auction are more expensive. One explanation is that the number of siblings is positively correlated with the quality of the sire due to the fact that demand creates its own supply. Most buyers seek for the progeny of famous stallions and breeders will produce more yearlings from good sires. Therefore, we observe a positive relationship between the yearling price and the number of siblings.

Table 10: Coefficients and t-values of the independent variables for different models

	Model B		Model C	
Variables	**coefficient**	**t-value**	**coefficient**	**t-value**
BMONTH	-0.092	-6.54***	-0.09	-6.43***
COLT	0.217	7.99***	0.218	8.01***
BAY	0.073	2.22**	0.065	2.42**
BROWN	0.004	0.11		
GREY	0.118	1.69*		
BLACK	0.147	0.7		
MIXED	0.017	0.29		
SAGE	-0.447	-5.2***	-0.423	-4.97***
SAGE2	0.031	5.19***	0.03	4.97***
SAGE3	-0.001	-4.93***	-0.001	-4.7***
SWIN	0.025	5.13***	0.023	4.94***
SCHAMP	0.225	6.87***	0.234	7.31***
DI	-0.014	-1.7*		
DAGE	-0.055	8.68***	-0.053	-8.64***
DWIN	0.032	4.27***	0.032	4.21***
RACEWIN	0.126	2.99***	0.162	4.62***
RACEWIN0	-0.066	-1.55		
DCHAMP	0.589	2.57***	0.591	2.56***
FOAL1	-0.062	-1.43		
WINSIBD	0.218	5.32***	0.234	5.97***
WINSIB	0.076	5.69***	0.073	5.58***
WIautumn	-2.354	-34.03***	-2.363	-34.45***
WIclassic	-1.237	-21.87***	-1.239	-22.13***
WIpremier	-0.993	-17.48***	-0.992	-17.57***
WIscone	-2.159	-27.35***	-2.17	-27.9***
MMadelaide	-1.309	-21.87***	-1.316	-22.06***
MMconrad	-0.732	-14.82***	-0.734	-14.97***
MMpremier	-2.094	-32.46***	-2.098	-32.6***
MMperth	-1.627	-27.35***	-1.615	-27.49***
MMnational	-1.756	-22.17***	-1.765	-22.32***

SAMESIRE	0.022	11.86***	0.023	12..03***
CONSTANT	14.016	34.19***	13.791	34.47***
R^2		0.5339		0.5327

Notes: 1. *, **, *** represent the 10%, 5% and 1% significance level respectively.

2. Model C is our final model and the significance level is set at 5%.

5.2 Sub-sample model

To smooth the high variation in prices and to find out the implicit price of each characteristic, we trim the top 1% observations and conduct the estimation based on the remaining 99% sample. This model also exhibits heteroskedasticity. Similar to the previous method, we use the White's estimation method to obtain consistent estimates of the variance. The estimation result is shown in Table 11.

Table 11: Coefficients and t-values of sub-sample model (Model D)

Variables	Coefficient	t-value
BMONTH	-4726.92	-5.8***
COLT	5451.42	3.26***
BAY	6635.41	3.31***
BROWN	1158.94	0.5
GREY	1580.71	0.39
BLACK	7583.09	0.64
MIXED	-33.87	-0.01
SAGE	-8731.09	-1.6
SAGE2	671.46	1.77*
SAGE3	-14.21	-1.75*

SWIN	-122.68	-0.45
DI	-426.41	-1.08
SCHAMP	12170.14	5.14***
DAGE	-2391.20	-6.84***
DWIN	1428.42	3.17***
RACEWIN0	-4226.91	-2.08**
DCHAMP	70260.50	-2.07**
FOAL1	-5400.92	4.91***
WINSIB	3664.89	2.38**
WIautumn	-116042.30	-22.36***
WIclassic	-100454.00	-19.45***
WIpremier	-87210.12	-15.72***
WIscone	-114917.00	-21.95***
MMadelaide	-96577.50	-18.21***
MMconrad	-66117.79	-11.99***
MMpremier	-112965.90	-22.08***
MMperth	-111173.90	-21.59***
MMnational	-100550.90	-16.55***
SAMESIRE	1319.76	8.27***
CONSTANT	215225.60	8.05***
R^2	0.4168	

Note: 1. Dependent variable= Price, the yearling price.

2. *, **, *** represent the 10%, 5% and 1% significance level respectively.

3 Model D is the benchmark sub-sample model.

The result of the sub-sample model is similar to that of the log-linear model with the full sample. Among the yearling specific factors, BMONTH is negatively related to the yearling price. On average, horses which are born one month later will be sold $4,727 less. Besides, colts are more valuable than filly by $5,451. Horses with bay skin color are more expensive when compared with other skin colors. The performance of the sire is positively related to the price in the log-linear model.

However, in the sub-sample model, the coefficient of SWIN is negative, though it is not statistically significant. For dam factors, all variables have results similar to those of the log-linear model. If the dam is one year older, the yearling price will fall by $2,391. The performance of the dam is positively related to the yearling price. Furthermore, buyers are willing to pay a high price for a sire or a dam with special championship. Having this kind of honor proves quality for a given sire or dam. The price of a yearling increases by $12,170 if its sire won any special championship and $70,260 higher if its dam won any special championship. Buyers priced the champion dams higher than champion sires because only a small number of dams can win a Horse of the Year Prize. For the auction dummy, the conclusion is similar to that of the previous model. The Australian Easter Yearling Sale is more popular and buyers are willing to pay more in this auction compared with other auctions.

For the goodness of fit, the R^2 of the sub-sample model is 0.4168, which is smaller than that of the log-linear model (0.5298).

Table 12 Coefficients and t-values of sub-sample model (Model D)

	Model E		Model F	
Variables	**coefficient**	**t-value**	**coefficient**	**t-value**
BMONTH	-4721.08	-5.8***	-4603.1	-5.61***
COLT	5255.75	3.13***	5249.52	3.13***

BAY	6306.26	3.1***	6105.08	3.65***
BROWN	963.55	0.41		
GREY	1105.03	0.27		
BLACK	7043.88	0.6		
MIXED	-5.30	0		
SAGE	-7965.64	-1.45	1035.26	4.53***
SAGE2	617.99	1.62		
SAGE3	-13.08	-1.6		
SWIN	-135.75	-0.49		
SCHAMP	11970.94	5.04***	12198.39	5.27***
DI	-443.21	-1.11		
DAGE	-2614.31	-7.26***	-2476.51	-7.3***
DWIN	1213.72	2.39**	1203.08	2.37**
RACEWIN	2974.44	1.16	4347.69	2.05***
RACEWIN0	-2653.91	-1.08		
DCHAMP	70265.24	2.38**	70738.17	2.39**
FOAL1	-3734.39	-1.4		
WINSIBD	6804.48	2.76***	7849.67	3.24***
WINSIB	2805.56	3.47***	2618.9	3.3***
WIautumn	-115951	-22.22***	-116276	-22.36***
WIclassic	-100629	-19.4***	-100777	-19.43***
WIpremier	-87334.9	-15.69***	-87396.5	-15.68***
WIscone	-115053	-21.84***	-115791	-22.04***
MMadelaide	-96757.6	-18.14***	-97118	-18.22***
MMconrad	-66546.2	-11.99***	-66810.4	-12.05***
MMpremier	-113027	-21.93***	-113544	-22.08***
MMperth	-111303	-21.44***	-111363	-21.71***
MMnational	-100661	-16.51***	-101044	-16.64***
SAMESIRE	1339.66	8.39***	1349.05	8.5***
CONSTANT	210784.1	7.88***	164176	16.55***
R^2	0.418		0.4169	

Notes: 1. *, **, *** represent the 10%, 5% and 1% significance level respectively.

2. Model F is the final model for 99% sub-sample.

Chapter 6. Discussion and Conclusion

6.1 Discussion

6.1.1 Racehorse as consumption good or investment good

After analyzing the effect of yearling specific characteristics and the bloodline effect on the yearling price, one important question that remains is why buyers are willing to pay such a high price for a racehorse given the uncertainty of its performance. Actually, there are three types of buyers. The first type of buyer buy a horse as an investment. A racehorse with a good bloodline has a higher chance to win in races. They are willing to pay for a high quality horse since the investment return is high. The prize money of international Grade 1 races is more than US$1million which attracts many horse owners to participate in those races. Table 13 shows the information of the World Racing Championships in 2005. The total prize money for each race is more than US$1million. Winning a Grade 1 race already covers the breeding cost and horse price. The Dubai World Cup is the most rewarding race in the world. The total prize money is US$6million. Besides, there are two more races which are the Dubai Duty Free Cup and the Dubai Sheema Classic. Both of them offer US$5million as prize money and they are the richest turf races in the world.

Such rewards are attractive enough for horse lovers to invest in a yearling with a good bloodline, despite the fact that such an investment is rather risky. Some outstanding racehorses do make a very considerable return to their owners. For example, Silent Witness is a Champion Sprinter and holds a world record since winning 17 consecutive races. It won around HK$58.7 million. After deducting the horse price, breeding expenses, insurance, commission to jockey and trainers, the net profit to its owner, Arthur Antonio da Silva is around HK$36 million within 4 years. The high prize money makes it very attractive for horse owners to invest in yearlings.

The second type of buyer buys yearlings for resale only. Professional horse traders and horse trainers may travel overseas to look for yearlings in some famous yearling sales. Since they are more familiar with recognizing potential horses, they buy the yearlings and raise them until they reach the age of two. As the ability of the racehorse will become observable when the horses become older, some horse owners are willing to pay a higher price in order to ensure the quality of the horse when it is mature. These investors bear the risk of miscalculating the yearling's potential. However, once the horse is transferred to another buyer, their return is realized. They do not have to bear the investment risk of an under-performed horse. The previous record holder of "the most expensive horse" is Seattle Dancer which was sold at

US$13 million in 1985. Although it has an excellent lineage and its half brother, Seattle Slew was the Triple Crown winner; it only won twice in its career life and generated only US$150,000 to its owners. After retiring, it was also unable to generate further earnings by its stud fee. Therefore, some investors solely resell the horses for profits rather than let their horses to race in track.

Table 13: Summary of "World Racing Championships in 2005"

Race	Date	Total Prize	Place
Audemars Piguet QE II Cup	24 April, 2005	US$1,800,000	Hong Kong
Singapore Airlines International Cup	15 May, 2005	US$1,800,000	Singapore
King George VI & Queen Elizabeth Diamond Stakes	23 July, 2005	US$1,248,000	England
Arlington Million	13 August, 2005	US$1,000,000	USA
Grosser Volkswagen Preis von Baden	4 September, 2005	US$1,000,000	Germany
Baileys Irish Champion Stakes	10 September, 2005	US$1,000,000	Ireland
Prix de L'Arc de Triomphe Lucien Barriere	2 October, 2005	US$2,442,000	France
Carlton Draught Cox Plate	22 October, 2005	US$2,347,000	Australia
Pattison Canadian International	23 October, 2005	US$1,624,000	Canada
John Deere Breeders' Cup Turf	29 October, 2005	US$2,000,000	USA
Breeders' Cup Classic Powered by Dodge	29 October, 2005	US$4,000,000	USA
Japan Cup	27 November, 2005	US$4,533,333	Japan
Cathay Pacific Hong Kong Cup	11 December, 2005	US$2,300,000	Hong Kong

The third type of buyer is a pure consumer. Horseracing has been a Royal spectator sport in England for hundreds of years. Most rich and noble families visit racecourse for entertainment and gathering with their business partners. It has become a luxury entertainment and therefore, it is commonly nicknamed as "The Sport of Kings". Raising a racehorse is costly. Therefore, owning a racehorse has become a symbol of prestigious status in society. For a racehorse to race in Hong Kong, the horse owner has to be a member of Hong Kong Jockey Club. Being a member of Jockey Club is by no means easy. A candidate must have the endorsement of two Voting members and must show that they are person of integrity in society. There are only 200 Voting members who have the right to nominate new members. The minimum membership fee is HK$36,000 and $320 every month. For corporate member, the fee is HK$1.2million for a 36 month membership or HK$2.4 million for a life membership. Corporate membership is by invitation only. Besides, raising a race horse is expensive. The expenses include renting a stable, employing horse trainers, grooms, veterinarians, buying food, etc., which amounts to around HK$30,000 a month. Only the rich and professionals can afford such expenses. This high-class entertainment gives the feeling of prestige and procures great happiness to horse owners once their horses have won a race.

Although the estimation of investment return for horseracing is important for buyers and breeders, it is difficult to obtain the information about the unnamed yearlings after they are sold. Auction companies only show the returns of successful graduates. Horses that have raced but did not win are not reported. The second-hand market is quite active but most of the transactions are dealt privately. Therefore, it is difficult to find the relevant information about private sales.

6.1.2 Other important variables affecting the yearling price

This study gives a brief understanding of how a yearling is priced under the uncertainty of its actual track performance. Under the common conception of family heredity, we show the importance of the performance of parents and siblings in yearling pricing. Apart from the factors that we have discussed, there are many other factors influencing the yearling prices. For example, the identity of the buyers may also affect the yearling price. Oversea buyers are usually more determined in buying a horse since they incurred a fixed cost in traveling. Besides, they typically have less information when compared with local buyers. So, we expect foreign buyers to pay more for a yearling. However, the existence of local agents makes it difficult to know

whether the real buyer is a local resident or a foreigner. So, we cannot include this variable into our model. On the other hand, physical condition of the yearlings plays an important role since it is the most direct factor affecting the development of a yearling. On top of the pedigree information, buyers also consider the horse's appearance, running posture and temper. Although the X-ray repository and the medical report of the horse are available upon request from the buyers, there is no objective measure for the physical appearance of the horses. Buyers have to rely on their own experiences to differentiate the physical condition of different yearlings. Thus, the physical appearance is difficult to be included in our pricing model.

6.2 Conclusion

It is clear that buyers are willing to pay more for a yearling with a good lineage. This phenomenon is built on the common knowledge of inheritance of ability. Without any track record of a yearling, the only way to quantitatively estimate the potential of a horse is to read its pedigree table. There are some successful racehorses such as "Show a Heart", "Canny Lad" which do not have a good lineage but perform very well in racecourse. Good parents may not be an assurance for the quality of the progeny but they make a good reference for the buyer to differentiate between

yearlings. The most expensive horse sold in the world was an unnamed two-year-old colt sold in 29th February 2006 at Calder Race Course. It was sold for US$16million. Although the colt has never raced, it was descended from two Kentucky Derby winners and showed off the fastest workout time among 154 horses up for bid. The bloodline effect still plays an important role in determining the yearling price. Besides, dams are equally important as sires in terms of inheritance, which is proven by modern biology.

Obviously, the physical features of yearlings like special preference in skin color, weight, bone structure, gender and birth month are also crucial. However, not all of them can be measured quantitatively. Furthermore, the performance of siblings is found to be a good indicator of the level of inheritance. We also show evidence that some auctions are more prestigious. This is the first study about the influence of popularity of auction on the yearling price. We show that the yearlings sold in the WI Australian Easter Yearling Sale and the MM Conrad Jupiters Yearling Sale have significant premium.

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Appendix 1

Stable 3 Rows G & H 1-8

On Account of BROADWATER FARM, Scone. (As Agent)

Lot 1 **BAY FILLY**

(Branded CR nr sh.$_4$ ^{30}off sh. Foaled 22nd October, 2004.)

(SIRE) **ELUSIVE QUALITY (USA)**	Gone West	Mr Prospector	by Raise A Native
		Secrettame	by Secretariat
	Touch Of Greatness	Hero's Honor	**by Northern Dancer**
		Ivory Wand	by Sir Ivor
(DAM) **RAAMI'S MAGIC** 1990	Raami (GB)	Be My Guest	**by Northern Dancer**
		Fast Motion	by Midsummer Night
		Beau Brummel (USA)	by Round Table
	Nummereen	Arctic Siren	by Messmate (GB)

By ELUSIVE QUALITY (USA) (B., 1993) Stakes-winner; won 9 races and $413,284 inc. Belmont Jaipur H. Gr 3; sire of the winners of over $US16m. and 21 SW's inc. Smarty Jones, Elusive City, Touch Of Quality, Girl Warrior, Elusive Diva, Omega Code, Chimichurri, Elusive Jazz, Gimmeawink, Shandy, Nasij, Courageous King, Great Notion, Elusive Chris, Adopted Daughter, Elusive Sara, etc.; his oldest Australian progeny are yearlings.

1st DAM

RAAMI'S MAGIC, *by Raami (GB)*. 10 wins 1080 to 3200m. TTC St Leger **L**, VATC Leica Show H., TRC Thorpe Transport Industries H., Graham Family H., J. Meaburn H., Maiden P., TTC Longford Cup, Victoria Bitter H., Ron Evans Memorial Cup, Don Heads H. 2d TRC Summer Cup, Hunter Island H., TTC Ron Evans Memorial Cup, Cybernetics Australia H. 3d VRC Collex Waste H., VATC Conbituate Lady H., TRC Fosters Light H., George Browne H. This is her third living foal, 1 raced, a winner-

CASUAL PASS *(g by Snippets)*. 5 wins - 4 in succession - 1400 to 2020m. and $701,100 inc. VRC L.K.S. Mackinnon S. **Gr 1**, MRC Norman Robinson S. **Gr 2**, MVRC Bill Stutt S. **Gr 2**, Visy Closed Loop H. 2d MRC Clive Leonard H., Knowledge H., MVRC Business Network Luncheon H. 3d MVRC Carlyon S. **Gr 2**, MRC St George S. **Gr 2**, Princess Talaria H.

2nd DAM

NUMMEREEN, *by Beau Brummel (USA)*. 4 wins at 1600, 1700m. 3d VATC Quezette H. Dam of 10 named foals, 8 raced, 6 winners –

RAAMI'S MAGIC. See above.

REPRICED. 9 wins 1080 to 1600m. TRC Raine/Horne Spring Series H., Cadbury Favourites H., Alan Trethewey Trophy, Land Rover Discovery H., Great Western H., Peter Sakos Memorial H., Yuletide H., CCI Insurance H.

LORD'S TAVERNER. 3 wins 1200 to 1600m. inc. VATC Ungar H.

MAGIC VIDEO. 2 wins at 1420m. TRC Carlton Genuine Draught H., Maiden P. 3d TRC Kelly's Steps H., Maiden H., Maiden P., twice.

ARDENT ARCHIE. 2 wins at 1200, 1800m. inc. WATC Class 6 H..

SMALL WAR. Won TTC Maiden P. (1600m.). 2d TTC N.E.F.U. H., Wells H.

FLYING SWORD. Unraced. Dam of 2 winners –

REGAL SWORD. 2 wins at 1600, 1920m. TRC Collex H., Bridles Restaurant Maiden P. 3d TRC N.A. Jones H., Saturday Tattslotto Maiden P.

PIRATE'S SIRENE. Won TTC John Dakin Financial. Maiden H. (1200m.).

3rd DAM

ARCTIC SIREN, *by Messmate (GB)*. 1 win at 1210m. Dam of 8 named foals, 6 raced, 2 winners inc. –

STRAE LADY. Placed. Dam of 2 winners –

RENOWNED GIFT. 6 wins at 1400, 1600m. and $270,596 inc. Sha Tin Stanley Bay H., Eau de Vie H. 2d Sha Tin Macwhinnie Cup.

MISS RED GUN. 1 win at 1600m. 3d TTC R.M. Bertram H.

Appendix 2

Test for heteroskedasticity

Breusch-Pagan test

Null hypothesis: H0: Constant variance

Chi2 (1) = 5.22

Prob>Chi2 = 0.0244

The result of the test indicates that the null hypothesis is rejected. The variance of fitted value is not constant.

Normality test for LNP model

Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
residual	4149	0.99962	0.875	-0.348	0.63594

The z-statistic is -0.348 and the null hypothesis is not rejected. The residuals of LNP model follow normal distribution. Figure 5 shows the normal quantile plot of residuals.

Figures

Figure 1a

Lot 224 sold at AU$1.2million in 2005 Australian Easter Yearling Sale

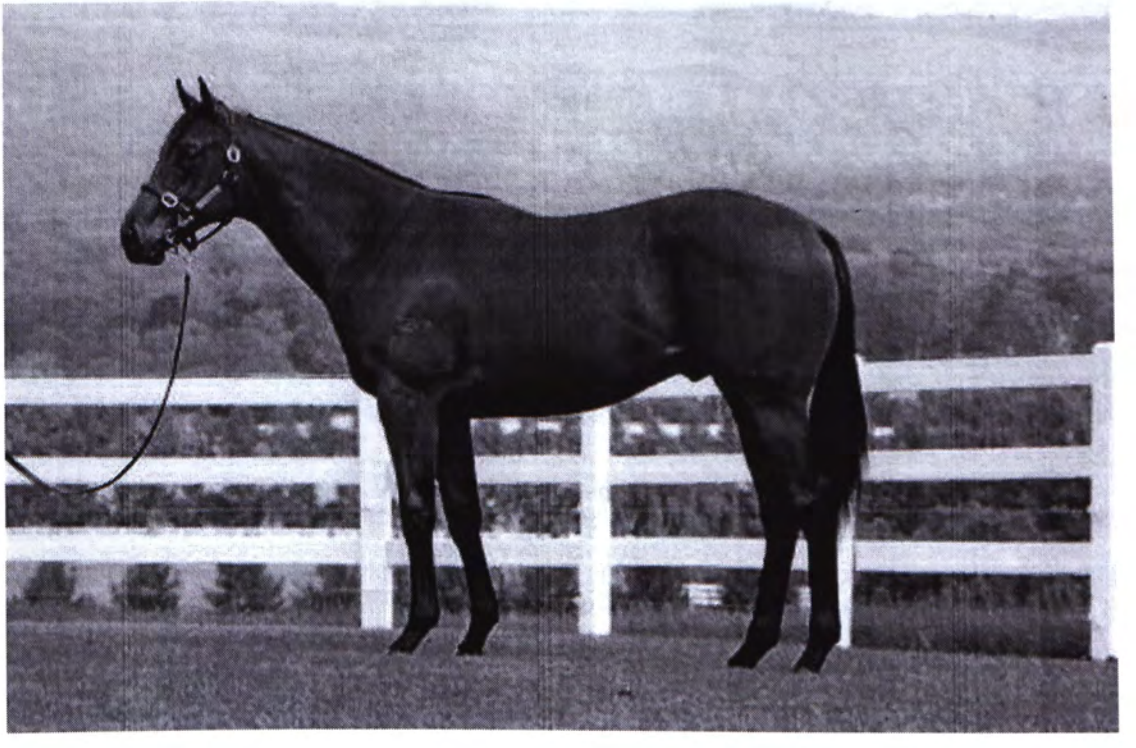

Figure 1b

Lot 77 sold at AU$50000 in 2005 Australian Easter Yearling Sale

Figure 2a

Histogram of the yearling price

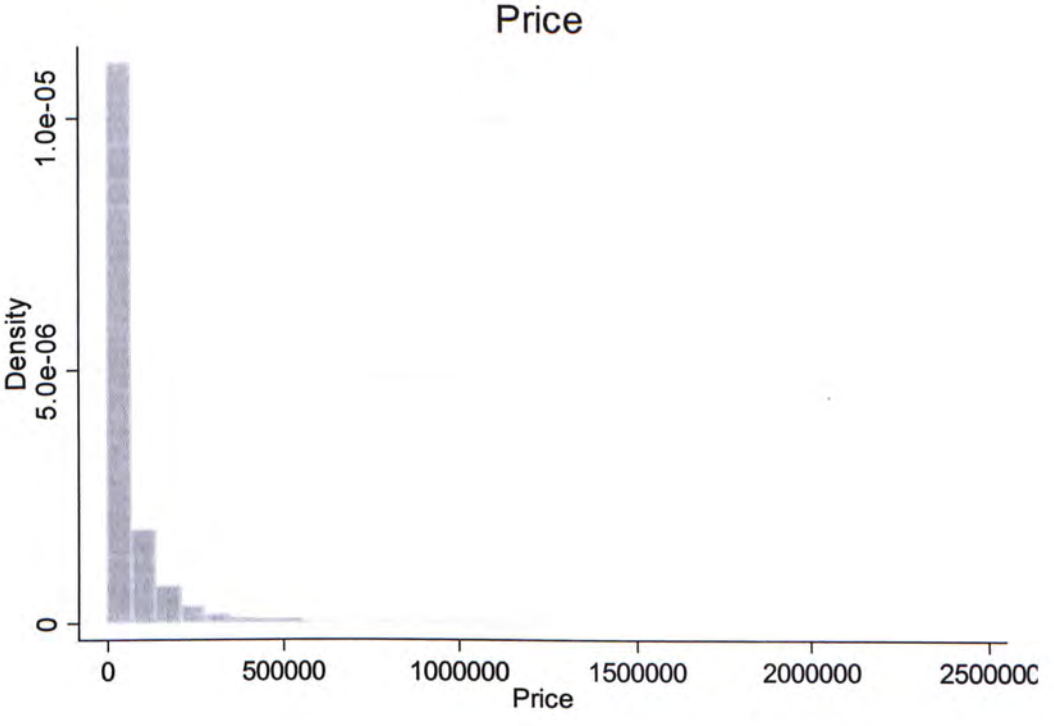

Figure2b

Histogram of natural logarithm of the yearling price

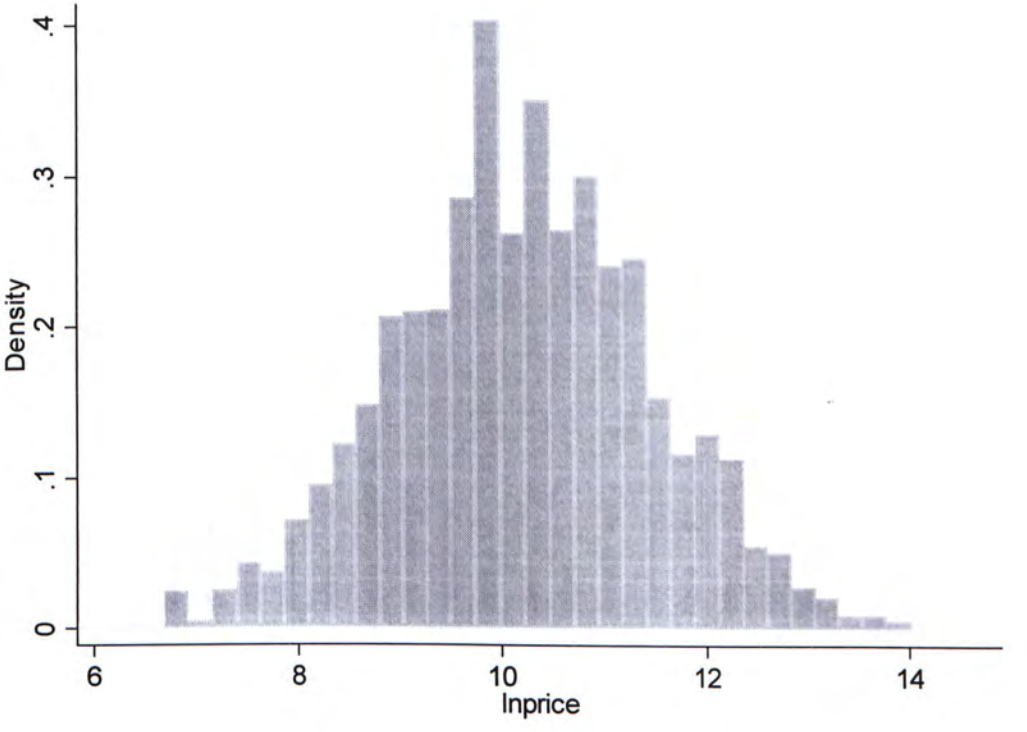

Figure 3a

Scatter plot for the relationship between the yearling price and SAGE

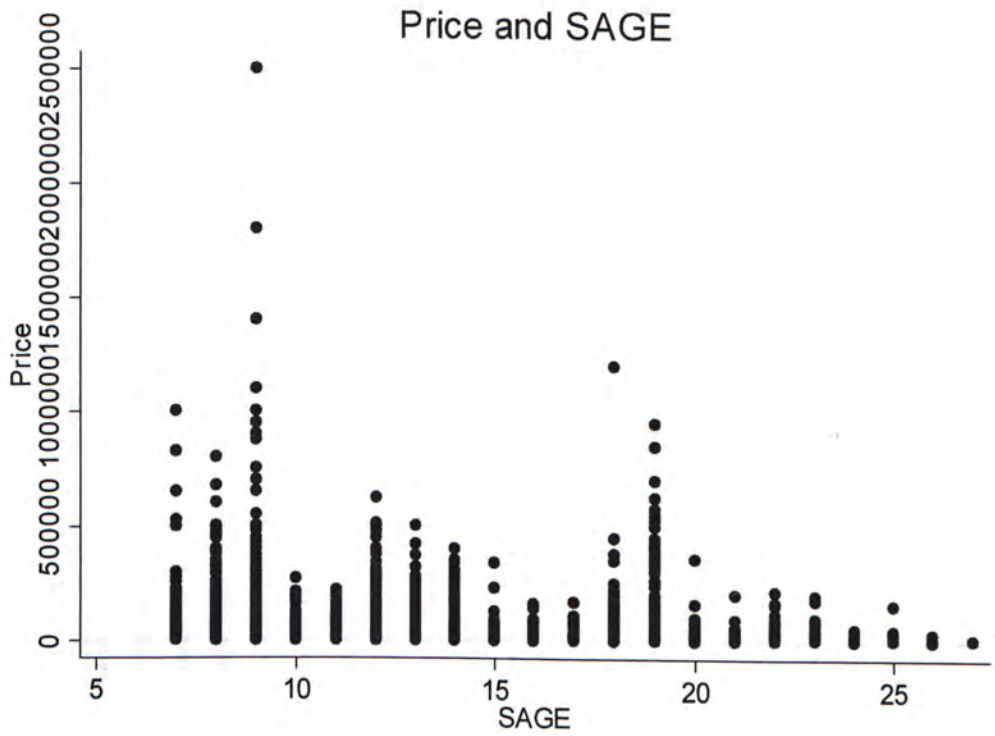

Figure 3b

Scatter plot for the relationship between the yearling price and DAGE

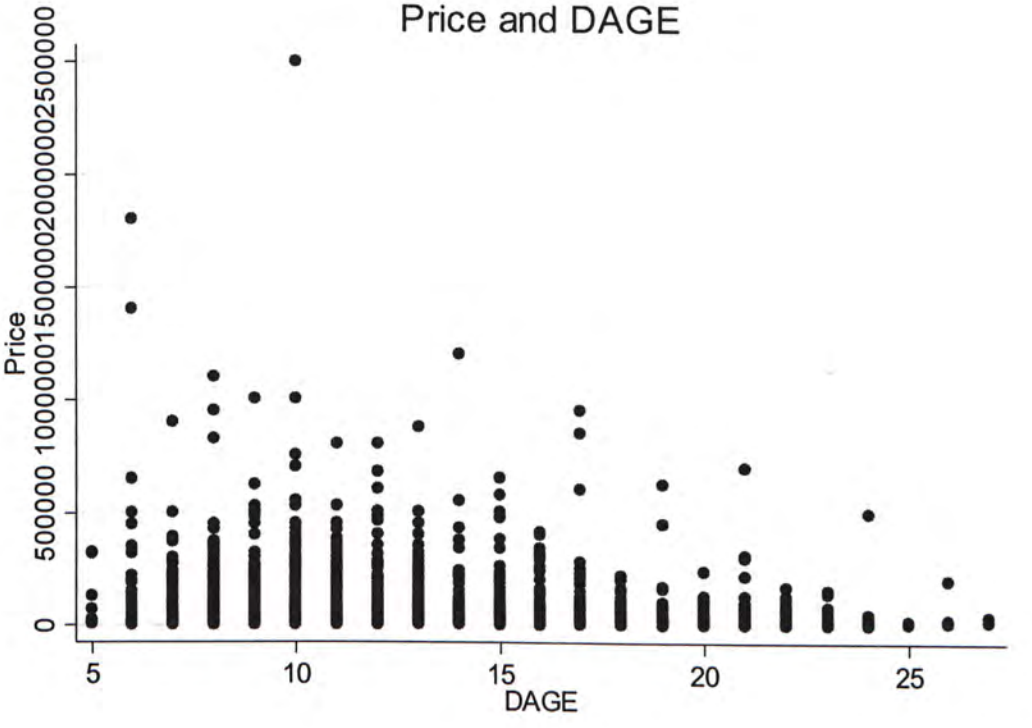

Figure 3c

Scatter plot for the relationship between the yearling price and AGE

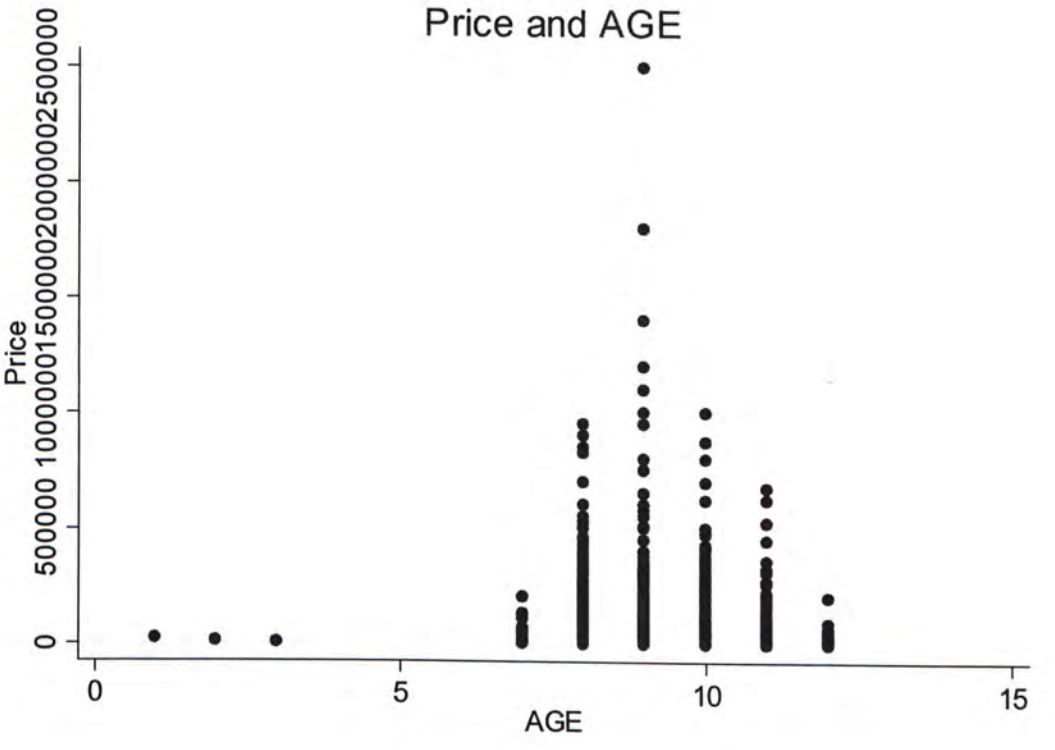

Figure 3d

Scatter plot for the relationship between the yearling price and SWIN

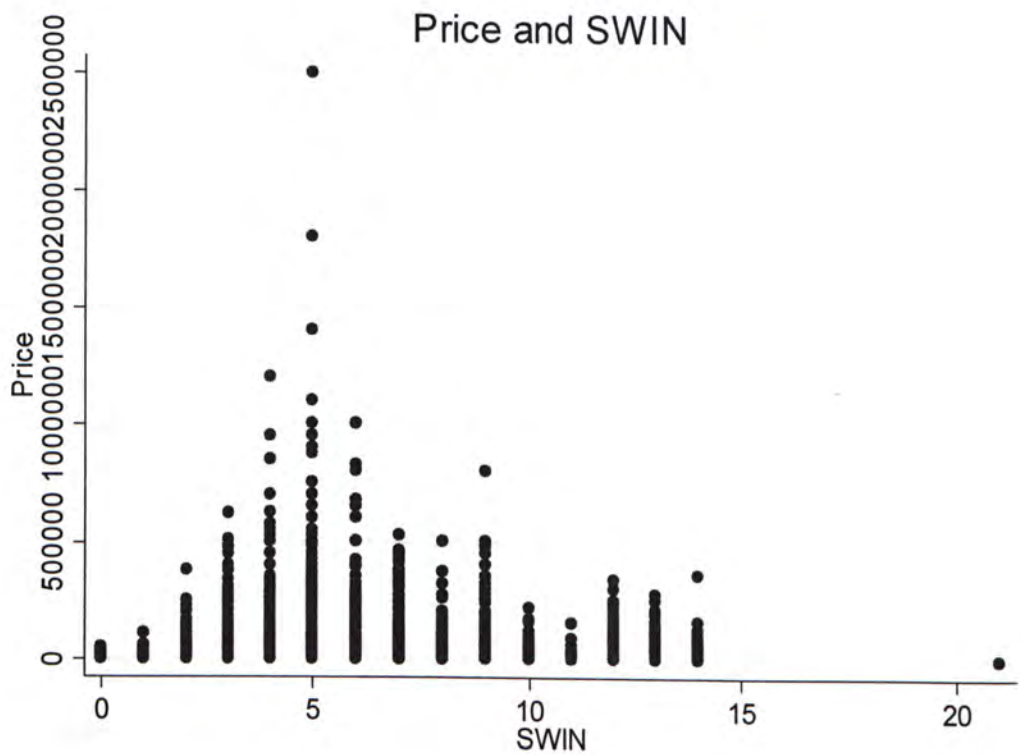

Figure 4

Growth rate of macroeconomic variables and the yearling price during 2001-2006

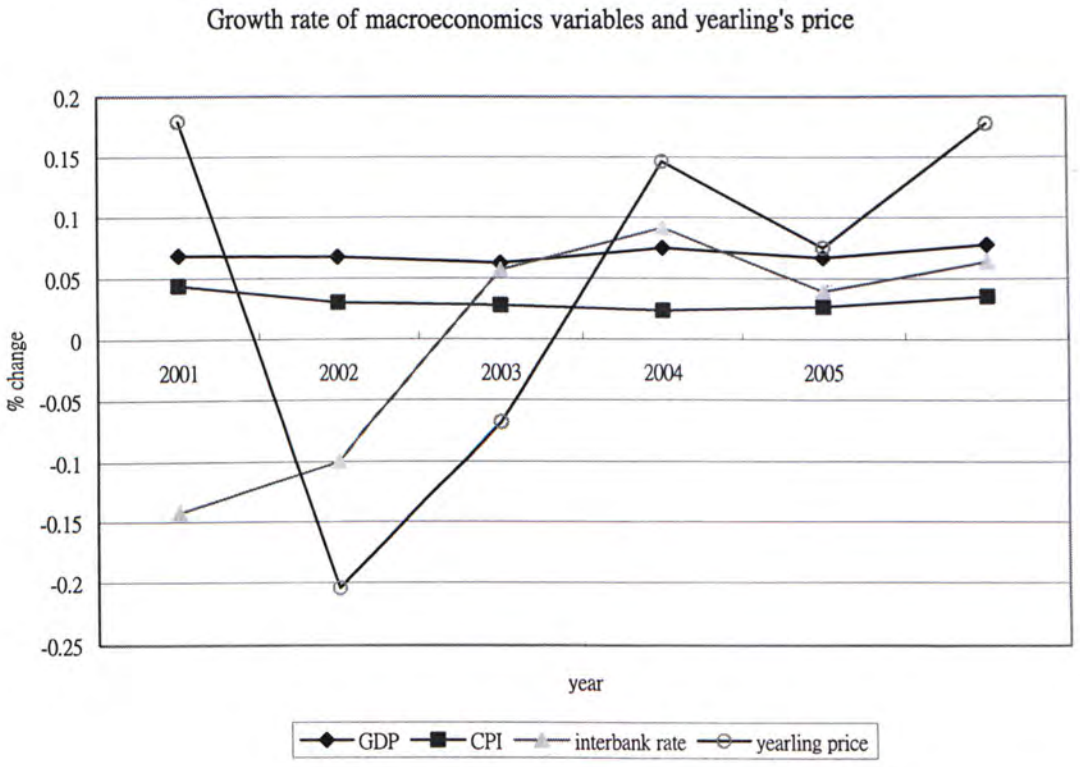

Figure 5

Normal quantile plot for LNP model